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ROTATIONAL BANDS OF EVEN-EVEN AXIALLY SYMMETRIC NUCLEI

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IT has been shown by Davydov and Filippov[1] that by using the Hamiltonian obtained by Ford[2] in averaging the interaction between the external nucleons and the nuclear core, one can write the equation for the collective motion of an axially symmetric even-even nucleus with total angular momentum $\hbar J$ in the form

$$d^2U_\nu/d\zeta^2 - 2\zeta dU_\nu/d\zeta + 2\nu U_\nu = 0, \qquad (1)$$

where U_ν satisfies the boundary condition

$$U_\nu(-\delta\xi) = 0, \quad U_\nu(\zeta)e^{-\zeta^2/2} \to 0, \quad \text{for } \zeta \to \infty. \qquad (2)$$

The eigenvalue ν of Eq. (1) is not in general an integer, and determines the energy $\epsilon_\nu(J)$ of the collective nuclear motion by the equation

$$\varepsilon_\nu(J)/\hbar\omega_0 = (\nu+{}^1/_2)\sqrt{1 + J(J+1)/\delta^4\xi^4} + J(J+1)/6\delta^2\xi^2 + {}^1/_2\,\delta^2(\xi-1)^2,$$
$$\xi^3(\xi-1) = J(J+1)/3\delta^4. \qquad (3)$$

Thus the energy of nuclear collective motion for each value of J = 0, 2, 4, . . . is determined uniquely by just the two parameters ω_0 and δ, which are related to parameters of Bohr and Mottelson's[3] generalized nuclear model by the expressions $\omega_0 = \sqrt{C/B}$, $\delta = \beta(BC/\hbar^2)^{1/4}$.

Davydov and Filippov[1] investigated the solution of Eq. (1) for the case $\delta \leq 1$. In this note we present the results of a solution of this set of equations for the case $\delta > 1$.

The figure gives a graph of $\epsilon_\nu(J)/\hbar\omega_0$ vs. δ; the numbers on the curves give the values of J. It is seen from the figure that when $\delta > 2.5$, the energy spectrum of collective excitations of even-even nuclei breaks up into a set of rotational-vibrational bands. In Table 1 we present a comparison of the theoretical excitation energies of the first and second rotational band for certain nuclei with the experimental data. We also give the values of $\hbar\omega_0$ and δ which have been used to calculate the theoretical excitation energy.

TABLE 1

Nucleus and literature reference	J	Energy level (kev)		$\hbar\omega_0$ (kev)	δ
		Theory	Experiment		
W^{182} [4,5]	2	100.09	100.09	1101	3.48
	4	320.3	329.36		
	6	641.6	677.6		
	0	1101	—		
	2	1222	1222		
	4	1481	1488.6		
Th^{232} [6]	2	50	50	710	3.93
	4	163	165		
	6	332	—		
	0	710	—		
	2	770	770		
	4	901	—		
U^{234} [5]	2	43	43	803	4.48
	4	141	142		
	6	290	295		
	0	803	803		
	2	855	—		
	4	966	—		
Pu^{238} [5]	2	44.2	44.2	935	4.73
	4	147.7	146		
	6	304.8	303		
	0	935	935		
	2	986	986		
	4	1100	1073		

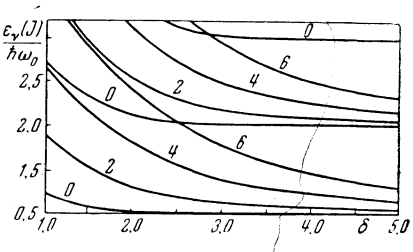
In Table 2 we give the δ dependence of the energy ratios of the first and second (1 and 2) rotational-state sublevels in the first and second (I and II) bands of the rotational states of the nucleus.

If the energy of collective oscillations is approximated in the form

$$E_J = n\hbar\omega_0 + AJ(J+1) - BJ^2(J+1)^2, \qquad A = \hbar^2/2I, \qquad B = a(\hbar\omega_0)^{-2}(\hbar/I)^3, \qquad (4)$$

TABLE II

δ	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
$\varepsilon_{1II}/\varepsilon_{1I}$	1.48	1.39	1.36	1.31	1.26	1.21	1.16	1.13	1.11
$\varepsilon_{2I}/\varepsilon_{1I}$	2.17	2.38	2.70	2.87	3.02	3.21	3.27	3.29	3.33
$\varepsilon_{2II}/\varepsilon_{1II}$	1.76	2.16	2.43	2.52	2.94	3.16	3.25	2.27	3.31



it follows from Table II that the moment of inertia I of the nucleus in the second rotational band is less than in the first. This decrease of I is greater for lower values of δ. The quantity a, which determines the coupling of rotational and vibrational states in Eq. (4), is greater in the second rotational band than in the first. Thus if one were to use Eq. (4) to describe collective oscillations, one would need five parameters, rather than the two that are needed to solve (1) with Eq. (3).

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MESONIUM AND ANTIMESONIUM

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GELL-MANN and Pais[1] were the first to point out the interesting consequences which follow from the fact that K^0 and $\tilde{K}^0$ are not identical particles.[2] The possible $K^0 \rightarrow \tilde{K}^0$ transition, which is due to the weak interactions, leads to the necessity of considering neutral K-mesons as a superposition of particles K_1^0 and K_2^0 having a different combined parity.[3] In the present note the question is treated whether there exist other "mixed" neutral particles (not necessarily "elementary") besides the K^0-meson, which differ from their anti-particles and for which the particle → antiparticle transitions are not strictly forbidden.

The laws of conservation of the number baryons and light fermions (or as sometimes called, conservation of nucleon[4] and neutrino[5] charge) strongly limit the number of possible mixed neutral particles. Because of the first-mentioned law mixed particles cannot occur amongst the baryons (e.g. a neutron; a hydrogen atom etc.), and because of the second law such particles cannot exist among the light particles with only one fermion (e.g. neutrino, the systems π^+e^- and π^-e^+, etc.).

From this it evidently follows that besides the K^0-meson the only system consisting of presently-known constituents which could be a mixed particle would be mesonium, defined as the bound system (μ^+e^-). Antimesonium, i.e., the system (μ^-e^+), clearly is different from mesonium and, furthermore, the